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Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

BENEFICIATION OF CYCLONE COAL DUST FROM QUEBEC IRON AND TITANIUM CORPORATION

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ORE PROCESSING LABORATORY
METALLIC MINERALS SECTION

APRIL 1977

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This report relates essentially to the samples as received

MICROMEDIA
JAN 10 1984

28 pp

MINERALS RESEARCH PROGRAM

MINERAL SCIENCES LABORATORIES
REPORT MRP/MSL (CF) 77-13 (IR)

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BENEFICIATION OF CYCLONE COAL DUST FROM QUEBEC IRON AND TITANIUM CORPORATION

BY A.I. STEMEROWICZ* AND G.W. LEIGH**

SUMMARY OF RESULTS

The sample of cyclone coal dust submitted for investigation contained 62.1% fixed carbon, 9.6% volatiles, 0.4% sulphur and 28.3% ash.

By employing flotation the coal dust was concentrated to 85.3% fixed carbon with a recovery of 90.1%. Kerosene and methyl isobutyl carbinol were employed as collector and frother respectively and it was only necessary to clean the rougher concentrate once to achieve the desired results.

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INTRODUCTION

Source of Sample

The coal dust is collected by cyclones from the anthracite coal dryers at the Quebec Iron and Titanium Corporation (QIT) plant in Sorel Quebec. Annual tonnage of this material is about 20,000 tons with an estimated value of over $1,000,000. At present the dust is disposed of by flushing into the sewage which discharges into the St. Lawrence river thus contributing to water pollution.

Shipment

Two 5-gallon cans containing approximately 100 lb of coal dust were received at the end of August 1976. They were marked as follows:

Coal dust from coal drier cyclone 29/07/76 (Sample No. 1)

Coal dust from coal drier cyclone 11/08/76 (Sample No. 2)

Nature of Investigation Requested

In his letter of May 20, 1976, Mr. Jerry Fong, Senior Chemical Engineer, Research Dept. of QIT stated the company wished to beneficiate the coal dust to +85% fixed carbon. The volatile content of this product would then be reduced to < 1% making it suitable for injection as a replacement for "Hy-car" presently purchased from Sorel-Metals Processing. The same flotation technique employed at CANMET for removing carbon from fly ash was being considered but QIT had neither the facilities or expertise to carry out flotation tests.

The formal request for an investigation was made by Mr. Fong in his letter of June 9, 1976 to the Director-General of CANMET. The investigation was to be of a preliminary nature involving about 10 flotation tests for an approximate cost of $2,000 not including analyses of test products which was to be done by QIT.

An interesting aspect of the investigation was that it could be related to three CANMET projects, viz., utilization of waste material, environmental protection and energy conservation.

Sampling and Analysis

The samples contained extremely fine dust which "puffed up" when disturbed. Therefore, in order to avoid dust losses no attempt was made to obtain a representative head sample by riffling. Instead, an equal amount of material was scooped from each can and mixed to make up the head sample. (This sampling procedure had been used previously in investigations on fly ash samples). Head sample analysis is compared in Table 1 with analyses of the material in each can as determined by QIT prior to shipment. Typical ash analysis as determined by QIT is given by Table 2 while Table 3 gives the distribution of the constituents in the various sieve fractions of the coal dust.

Table 1

Comparison of Coal Dust Analyses

Constituent %	CANMET Head Sample Comp of Samples 1 and 2	QIT Sample 1 Coal Dust Collected on 29-07-76	QIT Sample 2 Coal Dust Collected on 11-08-76
Fixed Carbon	62.13	63.79	63.77
Sulphur	0.39*	1.02	0.80
Ash	28.27	30.68	29.87
Volatiles	9.60	5.53	6.36

* Calculated from size analysis

Table 2

Typical Analysis of Ash in Coal Dust

Constituent	%
Fe_2O_3	22.2
Al_2O_3	19.7
CaO	1.5
MgO	1.6
SiO_2	43.5
TiO_2	5.9
MnO	0.09
Cr_2O_3	0.07
V_2O_5	0.15

Table 3

Distribution of Constituents in Coal Dust Sieve Fractions

Screen fraction mesh	Wt %	Analysis %				Distribution %			
		C	S	Ash	Vol	C	S	Ash	Vol
+65	11.4	79.14	0.40	12.80	8.06	14.3	11.6	5.2	10.4
-65, +100	7.9	73.43	0.37	18.71	7.86	9.2	7.4	5.3	7.0
-100, +150	11.0	66.67	0.35	25.75	7.58	11.6	9.8	10.1	9.4
-150, +200	11.1	61.65	0.33	30.28	8.07	10.9	9.3	12.0	10.1
-200, +325	18.3	64.29	0.35	27.10	8.61	18.7	16.3	17.7	17.8
-325, +400	4.8	61.86	0.39	29.00	9.14	4.7	4.7	5.0	5.0
-400, +500	10.5	62.73	0.41	27.89	9.38	10.4	11.0	10.4	11.1
-500	25.0	50.96	0.47	38.69	10.35	20.2	29.9	34.3	29.2
Total (calcd)	100.0	63.06	0.39	28.08	8.86	100.0	100.0	100.0	100.0
Total (assay)		62.13	0.05	28.27	9.60				

OUTLINE OF INVESTIGATION

A total of six flotation tests was carried out on the composite sample of coal dust. In the first five tests the standard technique of floating the coal away from the ash was employed while in the final test an attempt was made to float the ash away from the coal.

In all coal flotation tests a 4% emulsion of kerosene in water was employed as the coal collector and methyl isobutyl carbinol as frother. Variables investigated were as follows:

(1) Short grind prior to flotation,

(2) Washing out soluble salts prior to grinding and the use of a gangue dispersant in the grind,

(3) Lower flotation pulp density (11% solids vs 21% solids).

In the ash flotation test the feed was ground with a gangue dispersant and deslimed prior to flotation. A primary amine (Armac C) was used as the ash collector and Dowfroth 250 as the frother. Before ash flotation it had been intended to depress the coal by oxidation with hydrogen peroxide, but when it was observed that there was no "skin floating" coal this step was omitted.

Details of test procedure and material balances are given in the appendix. Also included in the appendix is a tentative flowsheet based on the best coal floation test accompanied by flowsheet design notes.

EVALUATION AND DISCUSSION OF RESULTS

Coal Floation

The best results for coal flotation were obtained when the sample was ground with kerosene prior to flotation. In this test (3) an 85.3% carbon concentrate with 90.1% recovery was obtained after only one stage of cleaning.

The results of the five tests are compared in Table 4. The criterion used in evaluating these tests is the separation efficiency* which is a quantitative measure of the extent of separation between the coal and ash.

As can be seen from Table 4 the highest separation efficiency was obtained in Test 3 for the first stage cleaner concentrate. In Test 5 in which a lower flotation pulp density was employed, separation efficiency was lower but this was offset by a higher concentrate grade.

Ash Flotation

Negative results were obtained for the ash flotation test. Fine coal floated in preference to the ash to give a froth product which assayed 84.1% fixed carbon and only 8.34% ash.

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*Separation Efficiency by N.F. Schulz, Transactions of the Society of Mining Engineers of AIME, Vol. 247, March 1970, pp 81-87

Table 4

Comparison of Results for Coal Flotation

Test No.	Product	Wt %	Analysis %		Distribution %		Sep Eff %	Remarks
			Fixed Carbon	Ash	Fixed Carbon	Ash		
1	Coal conc - final	48.2	86.62	6.79	64.3	11.5	52.8	Preliminary test using
	" " - first stage cleaner	56.0	85.46	7.69	73.7	15.1	58.6	kerosene as collector
	" " - rougher	64.7	83.06	9.69	82.7	22.0	60.7	and MIBC as frother
	" " - rougher + scav	74.8	81.53	10.92	93.9	28.7	65.2	
2	Coal conc - final	57.8	86.20	7.20	80.3	14.3	66.0	Repeat of Test 2 but
	" " - first stage cleaner	62.9	85.06	8.08	86.2	17.5	68.7	cut stage additions of
	" " - rougher	67.5	82.46	10.28	89.7	23.8	65.9	kerosene from 6 to 2
3	Coal conc - final	59.5	86.46	6.92	82.3	14.2	68.1	To try short condition-ing
	" " - first stage cleaner	66.0	85.29	7.87	90.1	17.9	72.2	grind with kerosene
	" " - rougher	70.1	82.78	9.98	92.9	24.1	68.8	prior to flotation
4	Coal conc - final	59.6	88.08	5.84	82.2	12.2	70.0	Similar to test 3 but
	" " - first stage cleaner	62.1	87.26	6.54	84.9	14.2	70.7	(1) washed out soluble
	" " - rougher	65.1	84.86	8.65	86.5	19.7	66.8	salts and (2) added dispersing agents to grind
5	Coal conc - final	62.9	87.30	6.80	85.4	15.1	70.3	Repeat of test 3 but
	" " - rougher	66.9	84.54	9.16	88.0	21.7	66.3	floated at a lower density

CONCLUSIONS AND RECOMMENDATIONS

The coal dust can readily be concentrated by using a standard coal flotation technique to give the required +85% fixed carbon concentrate grade with 90% recovery.

However, before a decision is made to design and build a full-scale plant to treat the coal dust it is recommended that:

I. A mineralogical investigation be carried out to determine the mode of occurrence of the ash. The findings of such an investigation might suggest modifications in treatment to improve results.

II. The treatment scheme be checked out in a pilot plant to specifically determine:

(1) the effect of various conditioning methods such as conditioning in a standard agitator, attrition scrubbing and a conditioning grind

(2) the optimum number of cleaning stages and whether or not it is advantageous to recirculate cleaner tailings

(3) whether or not reagent consumption can be significantly reduced by recirculating the tailings effluent as process make-up water.

It might also be advantageous to do some more batch testing to determine whether or not a cheaper petroleum by-product can be employed as a collector in place of kerosene.

APPENDIX

List of Abbreviations

Ker	Kerosene emulsion in water - 4% by weight using Hart Chemical Ltd. emulsifiers 25/4 (.105% by weight) and 25/J (.105% by weight)
MIBC	Methyl isobutyl carbinol (frother)
DF 250	Dowfroth 250 - Dow Chemical Co. water soluble frother
HMP	Sodium hexametaphosphate (dispersant)
ArmC	Armac C - Armour Industrial Chemical Co primary amine (cationic collector)
cl	cleaner
conc	concentrate
scav	scavenger
ro	rougher
tail	tailing
calcd	calculated

FLOTATION TEST REPORT

TEST NO 1	SAMPLE QIT Cyclone Coal Dust Composites	DATE Sept. 16/76
OBJECT OF TEST	Coal flotation using kerosene emulsion as collector and MIBC as frother	CHARGE 1000 g
		TESTED BY G.L.

OPERATION	Time min	% Solids	pH	Unit used	Reagents, Grams										
					Ker	MIBC	DF250								
Rougher flotation															
Stage 1	1/2	22	4.4	1000-g cell	0.2	0.04									
" 2	1/2				0.2										
" 3	1/2				0.2										
" 4	1/2				0.2	0.04									
Scavenger flotation															
Stage 1	1/2				0.2		0.02								
" 2	1/2				0.2		0.02								
Cleaners															
No. 1 - Stage 1	1/2	15	4.8	1000-g cell		0.02									
" 2	1/2					0.02									
" 3	1/2		5.0			0.02									
No. 2 - Stage 1	1	13	5.8	1000-g cell		0.02									
" 2	1/2		6.3			0.02									

REMARKS Coarse particles floated at end of rougher and in scavenger

METALLURGICAL BALANCE

TEST NO. 1	SAMPLE: QIT Cyclone Coal Dust Composite	DATE: Sept. 16/76

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		C	Ash	Vol	S				C	Ash			
Coal conc	48.2	86.62	6.79	6.59	0.48				64.3	11.5			
Coal cl tail - 2	7.8	78.29	13.27	8.44	0.49				9.4	3.6			
" " " - 1	8.7	67.61	22.61	9.78	0.48				9.0	6.9			
Scav conc	10.1	71.71	18.75	9.53	0.46				11.2	6.7			
Flotation tail	25.2	15.65	81.00	13.35	0.33				6.1	71.3			
Feed (calcd)	100.0	64.95	28.56						100.0	100.0			
Calculated Analyses													
1st stage cleaner conc	56.0	85.46	7.69						73.7	15.1			
Coal rougher conc	64.7	83.06	9.69						82.7	22.0			
Coal ro + scav conc	74.8	81.53	10.92						93.9	28.7			

REMARKS:

FLOTATION TEST REPORT

TEST NO 2	SAMPLE: QIT Cyclone Coal Dust Composite	DATE Sept. 17/76
OBJECT OF TEST:	Repeat of Test 1 but decreased stage additions of kerosene from 6 to 2 - also conditioned prior to flotation	CHARGE: 1000 g
		TESTED BY G.L.

OPERATION	Time min	% Solids	pH	Unit used	Reagents, Grams									
					Ker	MIBC								
Conditioning	5		4.0	1000-g cell	0.60									
Rougher flotation		22												
Stage 1	1				0.60	0.04								
" 2	1/2					0.02								
" 3	1/2					0.02								
Cleaners														
No. 1 - stage 1	1/2	15		1000-g cell		0.02								
" 2	1/2					0.02								
" 3	1/2					0.02								
No. 2 - stage 1	1	14		1000-g cell		0.02								
" 2	1/2					0.02								

REMARKS

METALLURGICAL BALANCE

TEST NO. 2 | SAMPLE: QIT Cyclone Coal Dust Composite | DATE: Sept. 17/76

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		C	Ash	Vol	S				C	Ash			
Coal conc	57.8	86.20	7.20	6.60	0.47				80.3	14.3			
Coal cl tail - 2	5.1	72.20	18.10	9.70	0.49				5.9	3.2			
" " " - 1	4.6	46.95	40.09	12.96	0.53				3.5	6.3			
Flotation tail	32.5	19.55	68.45	12.00	0.36				10.3	76.2			
Feed (calcd)	100.0	62.00	29.19						100.0	100.0			
Calculated Analyses													
1st stage cleaner conc	62.9	85.06	8.08						86.2	17.5			
Coal rougher conc	67.5	82.46	10.28						89.7	23.8			

REMARKS

FLOTATION TEST REPORT

TEST NO. 3	SAMPLE: QIT Cyclone Coal Dust Composite	DATE: Sept. 17/76
OBJECT OF TEST: Similar to Test 2 but employed a "conditioning" grind prior to flotation		CHARGE: 1000g
		TESTED BY: G.L.

OPERATION	Time min	% Solids	pH	Unit used	Reagents, Grams									
					Ker	MIBC								
Grinding	15	50%		*	0.6									
Rougher flotation														
Stage 1	1	22	4.0	1000-g cell		0.04								
" 2	1				0.6	0.04								
Cleaners														
No. 1 - stage 1	1/2	16		1000-g cell		0.02								
" 2	1/2					0.02								
" 3	1/2					0.02								
No. 2 - stage 1	1	15		1000-g cell		0.02								
"	1/2					0.02								

REMARKS:

* 8-in.-dia. ceramic ball mill with ceramic ball charge

METALLURGICAL BALANCE

TEST NO. 3 | **SAMPLE:** QIT Cyclone Coal Dust Composite | **DATE:** Sept. 17/76

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %					
		C	Ash	Vol	S				C	Ash				
Coal conc	59.5	86.46	6.92	6.62	0.45				82.3	14.2				
Coal cl tail - 2	6.5	74.65	16.55	8.80	0.46				7.8	3.7				
" " " - 1	4.1	42.71	43.59	13.70	0.47				2.8	6.2				
Flotation tail	29.9	14.72	73.58	11.70	0.31				7.1	75.9				
Feed (calcd)	100.0	62.44	28.99						100.0	100.0				
Calculated Analyses														
1st stage cl conc	66.0	85.29	7.87						90.1	17.9				
Coal rougher conc	70.1	82.78	9.98						92.9	24.1				

REMARKS:

FLOTATION TEST REPORT

TEST NO. 4	SAMPLE: QIT Cyclone Coal Dust Composite	DATE: Oct. 21/76
OBJECT OF TEST: Similar to Test 3 but (1) washed out soluble salts prior to grind and (2) employed dispersing agents in grind.		CHARGE: 1000 g
		TESTED BY: G.L.

OPERATION	Time min	% Solids	pH	Unit used	Reagents, Grams									
					Na_2CO_3	HMP	Ker	MIBC						
Conditioning **	5		3.5	1000-g cell										
Filtering														
Cake wash **														
Grinding	15	50	5.9	*	1.0	0.5								
Conditioning	10		8.0	1000-g cell	2.5		0.6							
Rougher flotation														
Stage 1	1	22	8.0					0.04						
" 2	1		7.7				0.6	0.04						
Cleaners														
No. 1 - stage 1	1/2	15	7.4	1000-g cell				0.02						
" 2	1/2							0.02						
" 3	1/2							0.02						
No. 2 - stage 1	1	14	7.2	1000-g cell				0.02						
" 2	1/2			"				0.02						

REMARKS: * 8-in.-dia ceramic ball mill with ceramic ball charge
** distilled water

METALLURGICAL BALANCE

DATE: Oct. 21/76

TEST NO. 4 | SAMPLE: QIT Cyclone Coal Dust Composite

PRODUCT	WT %	ANALYSIS %			DISTRIBUTION %	
		C	Ash	Vol	C	Ash
Coal conc	59.6	88.08	5.84	6.08	82.2	12.2
Coal cl tail - 2	2.5	67.88	23.00	9.12	2.7	2.0
" " " - 1	3.0	34.28	53.18	12.54	1.6	5.5
Flotation tail	34.9	24.79	65.52	9.69	13.5	80.3
Feed (calcd)	100.0	63.88	28.51		100.0	100.0
Calculated Analyses						
1st stage cl conc	62.1	87.26	6.54		84.9	14.2
Coal rougher conc	65.1	84.86	8.65		86.5	19.7

REMARKS:

FLOTATION TEST REPORT

TEST NO. 5	SAMPLE: QIT Cyclone Coal Dust Composite	DATE: Oct. 21/76
OBJECT OF TEST: Repeat of Test but employed lower flotation pulp density - 12% vs 22%		CHARGE: 500 g
		TESTED BY: G.L.

OPERATION	Time min	% Solids	pH	Unit used	Reagents, Grams									
					Ker	MICB								
Grinding	10	50	4.2	*	0.60									
Rougher flotation														
Stage 1	1	12	4.2	1000-g cell		0.04								
" 2	1				0.60	0.04								
Cleaners														
No. 1 - stage 1	1/2	8	5.2	1000-g cell		0.02								
" 2	1/2					0.04								
" 3	1/2					0.04								
No. 2 - stage 1	1/2		6.8	1000-g cell		0.02								
" 2	1/2					0.02								
" 3	1/2					0.04								

REMARKS: * 8-in.-dia. ceramic ball mill with ceramic ball charge

METALLURGICAL BALANCE

TEST NO. 5 | SAMPLE: QIT Cyclone Coal Dust Composite | DATE: Oct. 21/76

PRODUCT	WT %	ANALYSIS %							DISTRIBUTION %				
		C	Ash	Vol					C	Ash			
Coal conc	62.9	87.30	6.80	5.90					84.4	15.1			
Coal cl tail 1 + 2	4.0	41.24	46.26	12.50					2.6	6.6			
Flotation tail	33.1	23.23	66.87	9.90					12.0	78.3			
Feed (calcd)	100.0	64.23	28.28						100.0	100.0			
Calculated Analysis													
Coal rougher conc	66.9	84.54	9.16						88.0	21.7			

REMARKS

FLOTATION TEST REPORT

TEST NO. 6	SAMPLE: QIT Cyclone Coal Dust Composite	DATE: Oct. 27/76
OBJECT OF TEST: To try ash flotation using primary amine as collector with desliming prior to flotation*		CHARGE: 1000 g
		TESTED BY: G.L.

OPERATION	Time min	% Solids	pH	Unit used	Reagents, Grams									
					NaOh	HMP	CaO	Arm C	DF250					
Grinding	15	50	6.0	see test 4	2.0	0.5								
Desliming				10mm cyclones										
Conditioning	5		9.5				0.6							
Ash flotation				1000-g cell										
Rougher No. 1	1/2	22						0.05	0.04					
" No. 2	1							0.05	0.04					
No. 3	1/2													
No. 4	1/2		8.3					0.025	0.02					

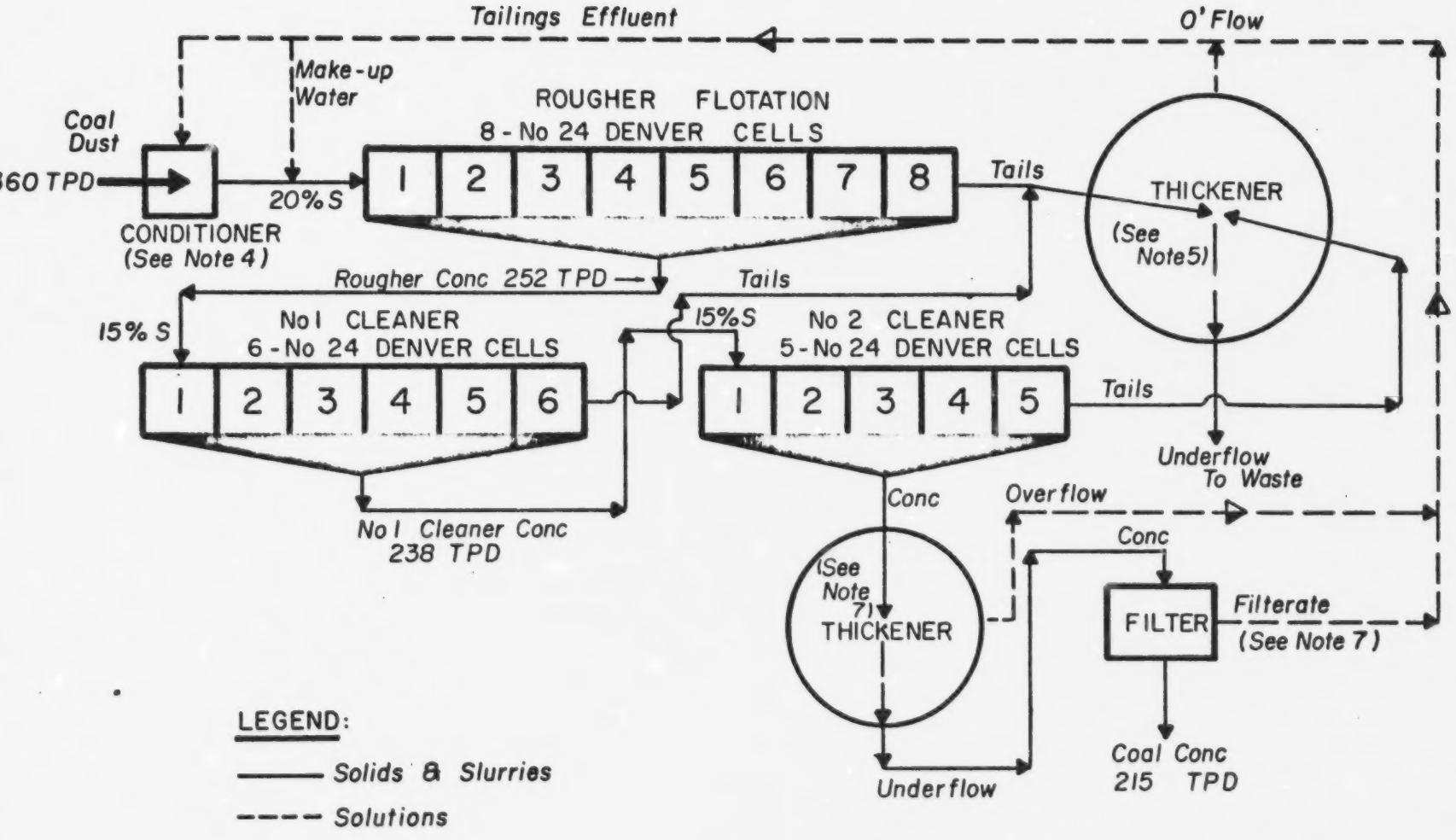
REMARKS: *Before ash flotation it had been intended to depress the coal by oxidation with hydrogen peroxide, but when it was observed that there was no "skin-floating" coal this step was omitted.

METALLURGICAL BALANCE

TEST NO. 6 | SAMPLE: QIT Cyclone Coal Dust Composite | DATE: Oct. 27/76

PRODUCT	WT %	ANALYSIS %			DISTRIBUTION %		
		C	Ash	Vol	C	Ash	Vol
Ash conc - 1	4.3	85.11	7.84	7.05	5.8	1.2	3.8
" " - 2	9.0	84.68	8.99	6.33	11.9	2.0	7.1
" " - 3	4.0	84.23	8.93	6.83	5.3	1.3	3.4
" " - 4	9.2	83.05	10.23	6.72	11.9	3.4	7.7
Flotation tail	69.1	57.81	34.14	8.05	62.6	84.4	69.2
Slimes	4.4	35.25	48.80	15.95	2.5	7.7	8.8
Feed (calcd)	100.0	63.77	27.96	8.04	100.0*	100.0	100.0
Ash conc - combined	26.5	84.12	8.34	6.67	34.9	7.9	22.0

REMARKS:



TENTATIVE FLOWSHEET FOR BENEFICIATION OF QIT COAL DUST

(Based On Test 3)

Design Capacity 360 TPD

DESIGN NOTES

1. Design capacity

Estimated yearly production of coal dust = 20,000 tons.

Plant to operate 5 days per week, day shift only.

Assume (1) 7 operating hours per shift

(2) 50 operating weeks per year = 250 days per year

$\frac{20,000}{250}$ = 80 tons/day or 12 tons/hour

To be on safe side assume a feed rate of 15 tons/hour.

2. Flotation time

Lab

Rougher 2 min @ 20% solids

No. 1 cleaner 1½ min @ 15% solids

No. 2 cleaner 1½ min @ 15% solids

Plant

In upscaling from batch to plant operation assume that a flotation time 5 times greater is required for both rougher and cleaners.

3. Flotation capacity

In calculating flotation capacity conditioning factor is used. It is the volume in cu. ft. necessary to give 1 min. contact for 1 ton per 24 hours.
From Denver tables C.F. for S.G. 1.4 (assumed S.G. for coal)

at 20% solids = 0.1048

at 15% solids = 0.1419

Rougher capacity

Tons per 24 hours = 15 x 24 = 360

Contact time required = 5 x 2 = 10 min.

Capacity in cu ft = 360 x 10 x 0.1048 = 377

No. of flot. cells required = 8 -No. 24 Denvers @ 50 cu ft = 400 cu ft

Cleaner capacity

1 Cleaner

Tons per 24 hours = 0.70 x 15 x 24 = 252

Contact time required = 5 x 1.5 = 7.5 min

Capacity in cu ft = 252 x 7.5 x 0.1419 = 268

No. of flot. cells required = 6 - No. 24 Denvers @ 50 cu. ft. = 300 cu ft

2 Cleaner

Tons per 24 hours = 0.66 x 15 x 24 = 238

Contact time required = 5 x 1.5 = 7.5 min.

Capacity in cu ft. = 238 x 7.5 x 0.1419 = 253

No. of flot. cells required = 5 - No. 24 Denvers @ 50 cu ft. = 250 cu ft

4. Conditioning

Choices (further testing needed to determine type of conditioning required).

(1) 6 x 6 Denver conditioner to give 5 min contact time.

(2) small ball mill for polishing grind

(3) 2-cell 32 in. x 32 in. Denver attrition scrubber.

5. Tailings Thickener

Pilot plant testing is required to determine whether or not it is advantageous to recirculate tailings effluent as process water. Feed rate would be 145 dry tons per 24 hours at about 9% solids.

6. Concentrate Thickener

No data available to determine size required.

7. Concentrate Filter

No data available to determine size required
feed rate would be 215 dry tons per 24 hours.

8. Reagent feeders

According to lab additions 9 reagent feeders would be required but pilot plant testing would be required to confirm this.
Total reagent consumption in the lab. test was:

Kerosene 2.4 lb/ton
Methyl isobutyl carbinol 0.36 lb/ton

POOR

QUALITY

ORIGINAL